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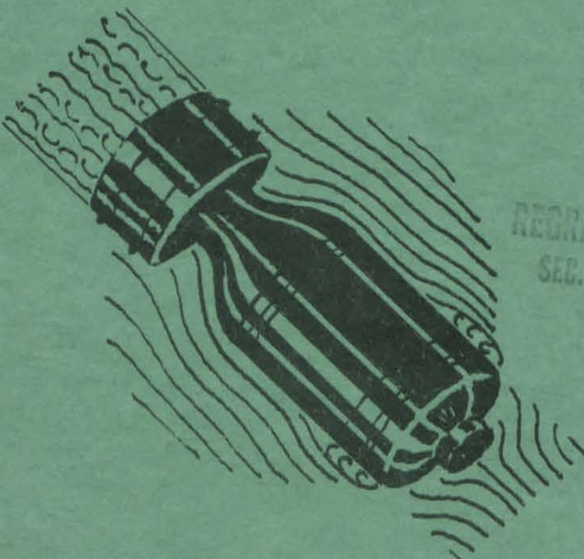
PRESSURE DISTRIBUTION
ON THE
MK-13 SERIES TORPEDOES WITH SHROUD RING TAILS



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THE HIGH SPEED WATER TUNNEL
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SECTION Nº 6.1 - sr 207-1905
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PRESSURE DISTRIBUTION ON THE MK-13 SERIES TORPEDOES WITH SHROUD RING TAILS

ROBERT T. KNAPP
OFFICIAL INVESTIGATOR

THE HIGH SPEED WATER TUNNEL
AT THE
CALIFORNIA INSTITUTE OF TECHNOLOGY
HYDRAULIC MACHINERY LABORATORY
PASADENA, CALIFORNIA

Section No. 6.1-sr207-1905
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Report Prepared by

Joseph Levy
Hydraulic Engineer

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FIGURE 1

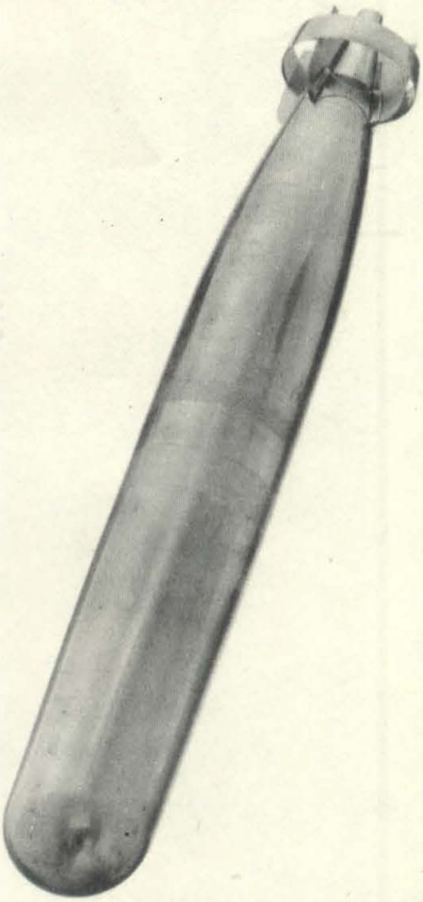

FIGURE 2

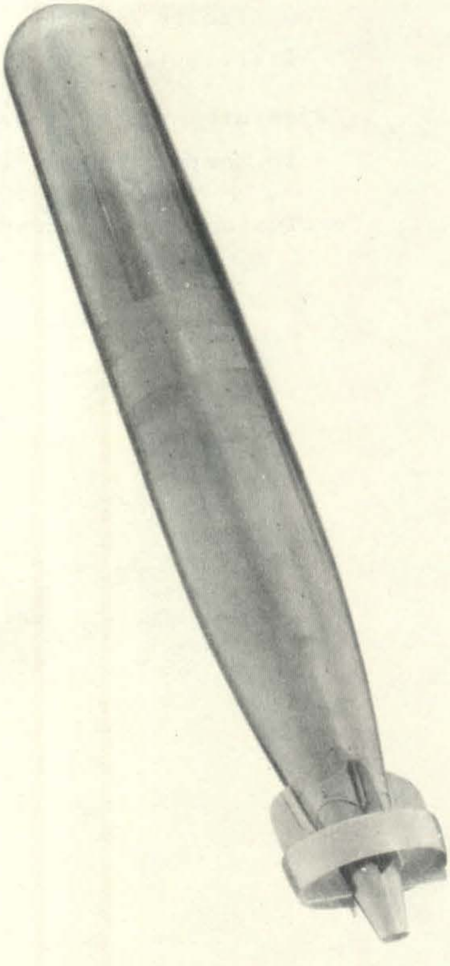

FIGURE 3

THREE VIEWS OF THE MODEL

PRESSURE DISTRIBUTION MEASUREMENTS
ON THE
MK 13 SERIES TORPEDOES
WITH RING TAILS

I. INTRODUCTION

This report is a supplement to a previous report of this laboratory entitled "Pressure distribution Measurements on the MK 13-1, 13-2, and 13-2A Torpedoes", file marked Section No. 6.1-sr207-1643, and dated June 23, 1944. It is a part of the program of investigation requested and authorized by Dr. E. H. Colpitts, Chief of Section 6.1 of the National Defense Research committee, in a letter dated October 8, 1943.

The preceding report, referred to hereafter as Report 1643, included measurements of the pressure distribution about the bare hull and about the hull with fins but without shroud ring tail. The tests reported herein cover pressure distribution measurements on the torpedo with fins and shroud ring tail.

The main objective of these investigations was to determine whether or not the depth control mechanism is actuated by true hydrostatic pressure. This is of interest because the immersion mechanism can keep the torpedo at set depth only if it is actuated by true hydrostatic pressure of the water at the running depth, and if this pressure is unaffected by variations in speed and in yaw or pitch angles.

The pressure distribution measurements on the torpedo with fins but without ring (covered in Report 1643) indicated that, with the original arrangement, the immersion mechanism is actuated by a pressure which is lower than true hydrostatic pressure. This would cause the torpedo to run below set depth. Furthermore, it so happens that the depth and roll recorder is located on the exercise head where it, also, is subject to a pressure lower than true hydrostatic pressure and, therefore, records a running depth which is shallower than the actual depth. With this combination of circumstances, the torpedo runs several feet below set depth while, at the same time, the depth and roll record indicates that the run was made at or near set depth. A definite recommendation was made in Report 1643 for the relocation of the pressure intake to the immersion mechanism on the ringless torpedoes so that the mechanism will be actuated by true hydrostatic pressure. It was suggested also that the data contained in that report may be used to determine the correction to be applied to the depth record obtained with the depth and roll recorder in its present location.

The present tests were made to determine whether the presence of the ring affected the pressure distribution on the afterbody. That is, whether the torpedoes with ring tails would require a different location for the pressure intake than the one recommended for the ringless torpedoes.

Pressure measurements were made on the afterbody only, since it was expected that the influence of the shroud ring would not extend to the forebody. The test results justified this assumption.

These tests showed that the presence of the shroud ring on the tail does not affect the pressure distribution on any part of the torpedo body. Therefore, the conclusions and recommendations given in Report 1643 for the ringless torpedo apply also to the torpedo with ring tail. These conclusions and recommendations are summarized on Pages 15 and 16 of this report.

II. APPARATUS AND TEST PROCEDURES

The apparatus and test procedures used in these tests were identical with those used in the tests covered in Report 1643 and, therefore, only a brief description will be given here.

The model shown in Figures 1 to 4, consists of a forebody, afterbody, and separate tail cone, all supported by the spindle-mounted center section. A new tail cone was made for these tests and was fitted with fins, with rudders fixed in neutral position, and with a shroud ring similar to the ring now in service. Each part is so made that it can be rotated about the longitudinal axis independently of the other parts. Thus a single row of pressure taps is sufficient to explore the pressure around the entire body.

The pressure was measured by a differential pressure gage having a flat-tube helical element, the free end of which is attached to a swinging mirror. A ray of light from a straight-filament bulb is reflected by the mirror onto a curved scale.

The pressure distribution around the torpedo was explored by setting the piezometer taps at a given angle with the vertical center line and measuring the pressure at each tap for yaw angles of -6 to +6 degrees in three-degree intervals. The piezometer tap settings were varied from 0 to 90° in 15° steps. The tests were made with a water velocity of 32 feet per second and constant static pressure in the tunnel working section of 10 psi.

The static pressure reference was taken at the tunnel wall at a point 5.25 model diameters upstream of the nose. The differential pressure measured at each piezometer opening was corrected for tunnel pressure gradient by subtracting from it the tunnel pressure drop, measured in the absence of the model, between the reference point and a point opposite that piezometer opening.

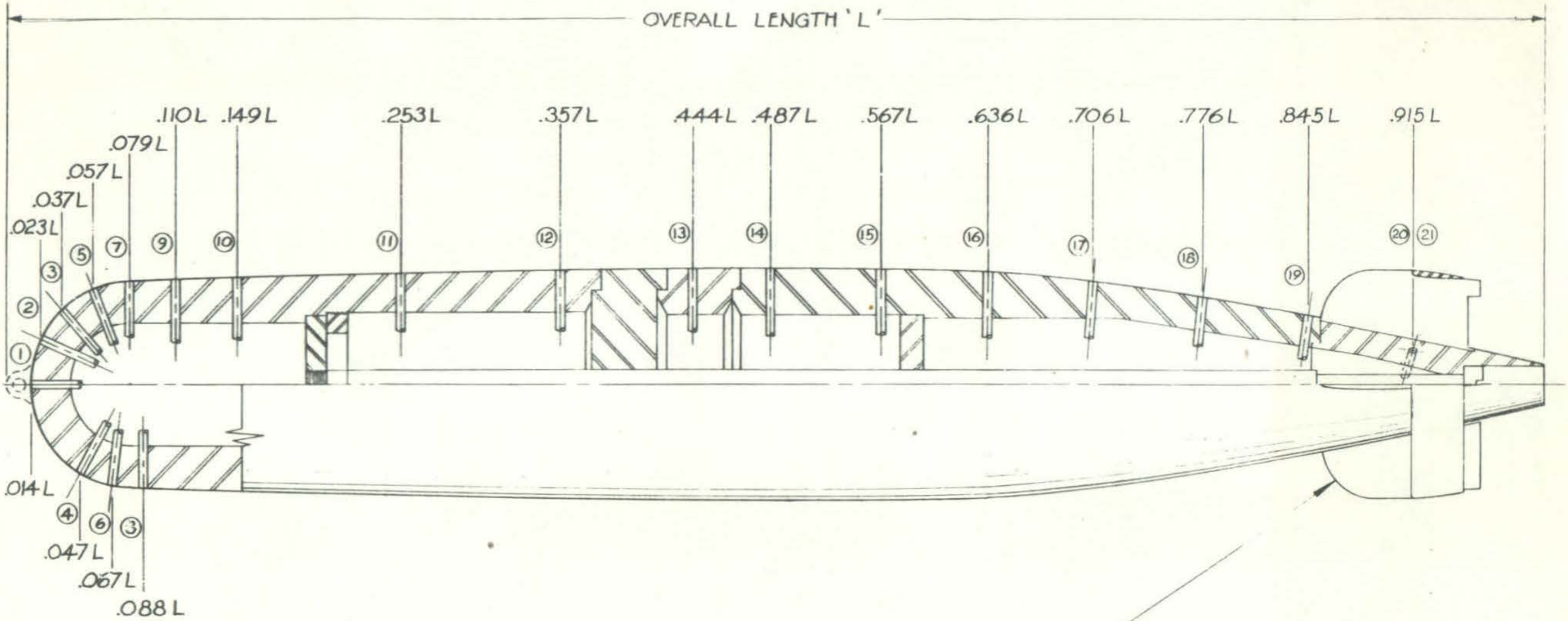

FIGURE 4

TAPS 4, 6 & 8 ARE ON HORIZONTAL ℄.
SHOWN ROTATED 90° OUT OF POSITION.

HORIZONTAL FIN & FIXED RUDDER
ROTATED 90° OUT OF POSITION

ANGULAR LOCATION OF NOSE TAPS

TAP NO.	ANGLE FROM AXIS
1	0°
2	30°
3	50°
4	60°
5	70°
6	80°

TWO TAPS NO. 20 & 21 LOCATED 45° EACH
SIDE OF PORT HORIZONTAL FIN

PRESSURE TAP LOCATIONS
MK. 13-1, 2 & 2A TORPEDOES

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III. TEST RESULTS

The test results are shown in Figures 5 to 13, inclusive, and are presented in terms of p/q, where

$p = P - P_o$

P = pressure on the surface of the torpedo, pounds per square foot

P_o = static pressure in undisturbed water at same level as torpedo center line, pounds per square foot

$q = 1/2\,\rho\,V^2$ = dynamic pressure of water, pounds per square foot

ρ = mass density of water, slugs per cubic foot

V = mean water velocity, feet per second

Data from tests covered in Report 1643 were used in drawing the pressure distribution on the forebody, since the present tests were made on the afterbody only.

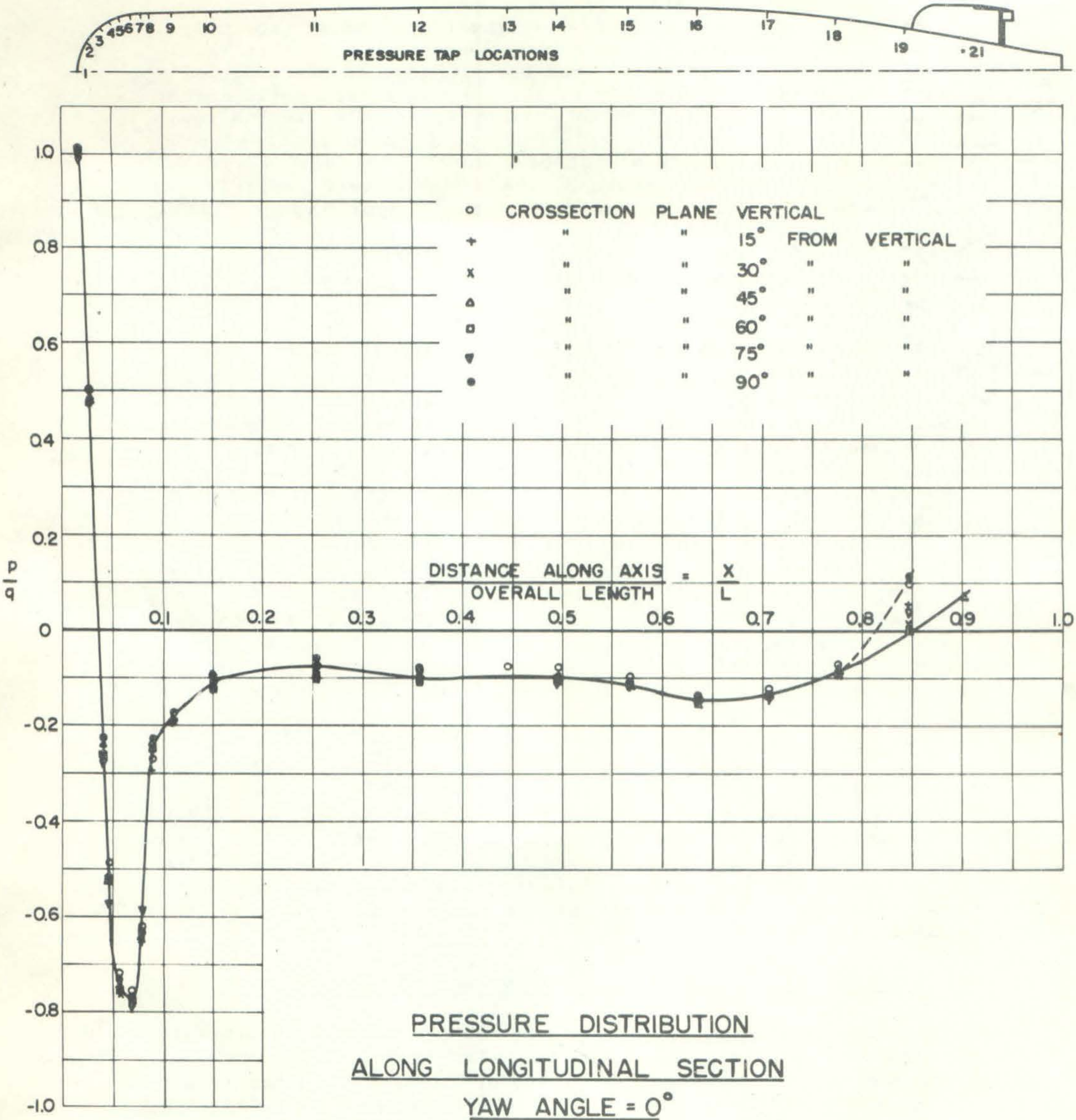
LONGITUDINAL PRESSURE DISTRIBUTION - ZERO YAW

In Figure 5 is shown the longitudinal pressure distribution around the torpedo with ring tail and at zero yaw, plotted against distance from the tip of the towing ring, expressed as a fraction of the overall length.

Referring to Figure 4 again, it will be noted that the standard overall length of the torpedo is assumed to include the towing ring on the nose, whereas the pressure distribution model was constructed without this ring, in order to locate a piezometer opening on the axis. This explains why the stagnation pressure does not occur at zero length.

From full stagnation pressure at the tip of the nose, the pressure drops very rapidly to about 0.78 q below static and then rises again, but remains below static pressure over almost the entire length of the torpedo. Static pressure ($p/q = o$) occurs at two stations on the body, one on the nose and one on the afterbody. It will be noted that on piezometer tap No. 19, the pressure is higher when immediately in front of a fin (0° and 90° positions) than it is for all positions between the fins.

Figure 5 gives the same information about the torpedo with ring tail as given for the ringless torpedo in Figure 8 of Report 1643. A comparison of these two figures shows that the presence of the ring has no appreciable effect on the pressure distribution.



PRESSURE DISTRIBUTION

ALONG LONGITUDINAL SECTION

YAW ANGLE = 0°

BODY WITH RING TAIL

FIGURE 5

YAW EFFECTS ON LONGITUDINAL PRESSURE DISTRIBUTION

Figure 6 shows the pressure distribution along a longitudinal section at right angles to the plane of yaw or pitch as it is affected by yawing or pitching. From the symmetry of the body it is evident that these curves apply to the top and bottom meridians of the torpedo as it yaws to port or starboard, and also to the horizontal meridians along both sides as the torpedo pitches up or down. It is seen that the effect of yaw or pitch is to lower the pressure over the entire length of the torpedo, very slightly for angles below 3°, and more noticeably for larger angles. This figure corresponds to Figure 10 of Report 1643 which refers to the ringless torpedo. Again by comparing these two figures it is seen that the ring does not materially affect the pressure distribution.

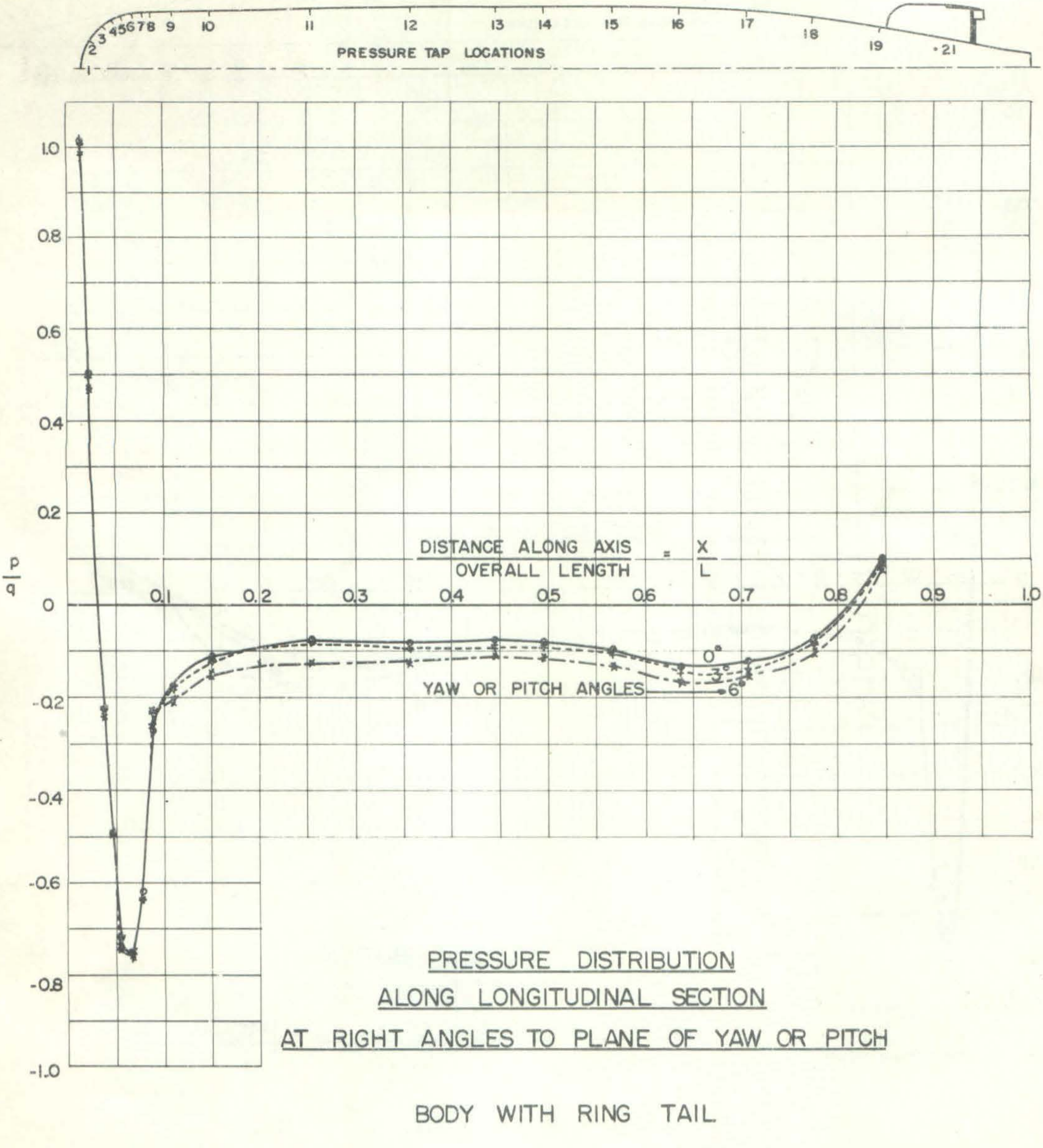
In Figures 7 and 8 is shown the longitudinal pressure distribution on the windward and lee side, respectively, of the torpedo with ring tail along the meridians at 45° with the plane of yaw or pitch. These curves show that yaw or pitch causes the pressure on the nose to increase on the windward side and to decrease on the lee side. Along the middle of the torpedo the pressure on both sides decreases with yaw, and near the tail the pressure decreases with yaw on the windward side and increases slightly on the lee side. These two figures give the same data for the torpedo with ring as given for the ringless torpedo in Figures 13 and 14 of Report 1643. These show again that the ring does not have any noticeable effect on the pressure distribution. By the addition of pressure taps 20 and 21 on the tail with ring, it was possible in these test to measure the pressure farther aft on the body than was done in the tests of Report 1643 on the torpedo with fins but without ring.

Figures 9 and 10 show the longitudinal pressure distribution on the windward and lee side, respectively, of the torpedo with ring tail along a section in the plane of yaw or pitch. These are comparable with Figures 17 and 18 of Report 1643. It is seen that these do show some slight variation in the pressure at the tail with and without ring. However, these variations are no larger than the probable error of the tests and, therefore, may be neglected.

PRESSURE AROUND CROSS SECTIONS NORMAL TO TORPEDO AXIS

In Figures 11, 12, and 13 are plotted the transverse pressure distributions around cross sections taken normal to the axis of the torpedo at each piezometer opening or station. Figures 11 and 12, showing the pressure distribution around the forebody, were taken from Report 1643 (Figures 19 and 20 in that report), since pressure measurements on the forebody were not made in the present series of tests.

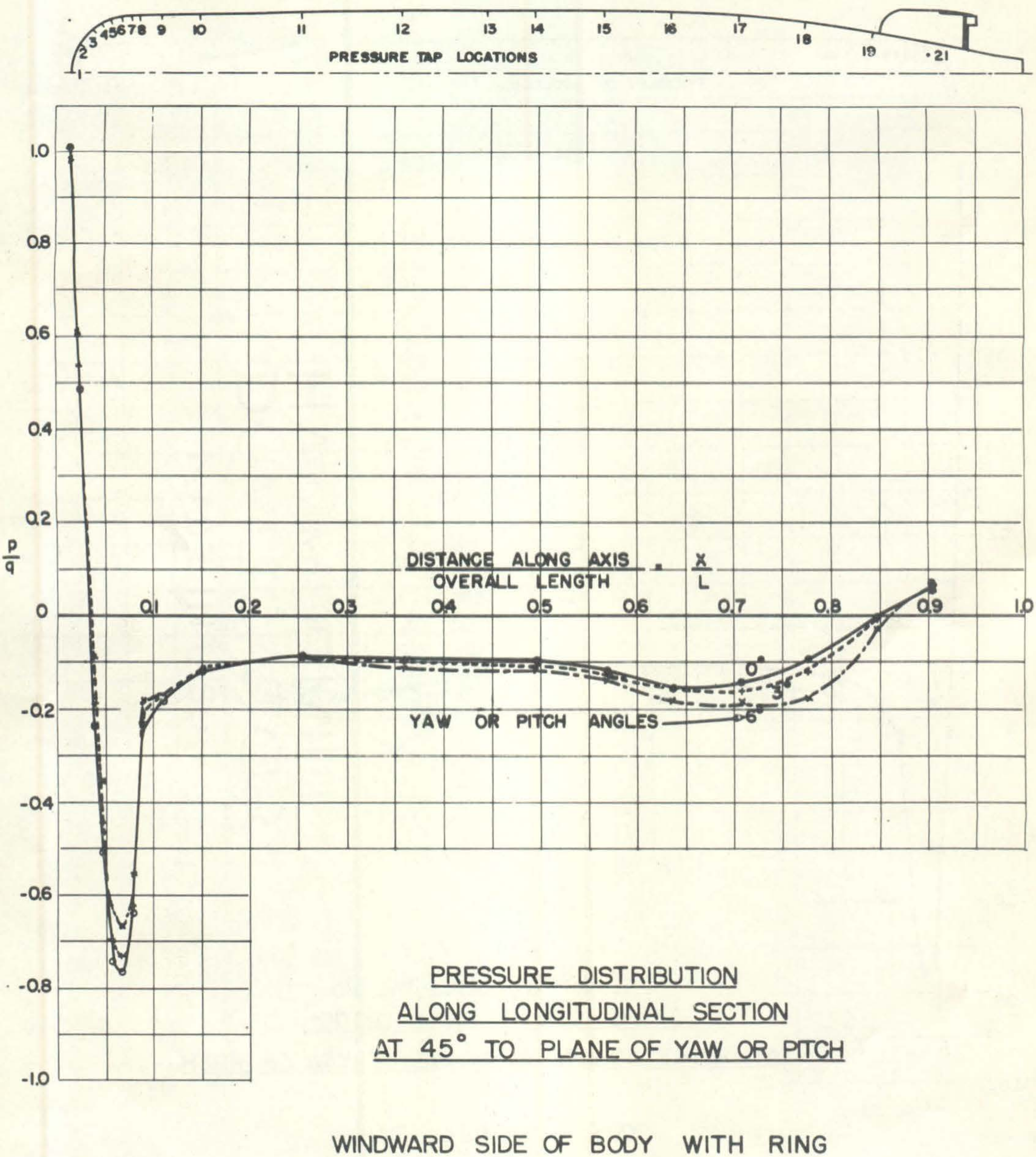
The curves of Figures 11 to 13 show the pressure for yaw angles of 0, 3, and 6 degrees, plotted against body angles measured to either side from the vertical center line. Because of the symmetry of the body it is evident that these curves give also



PRESSURE DISTRIBUTION
ALONG LONGITUDINAL SECTION
AT RIGHT ANGLES TO PLANE OF YAW OR PITCH

BODY WITH RING TAIL

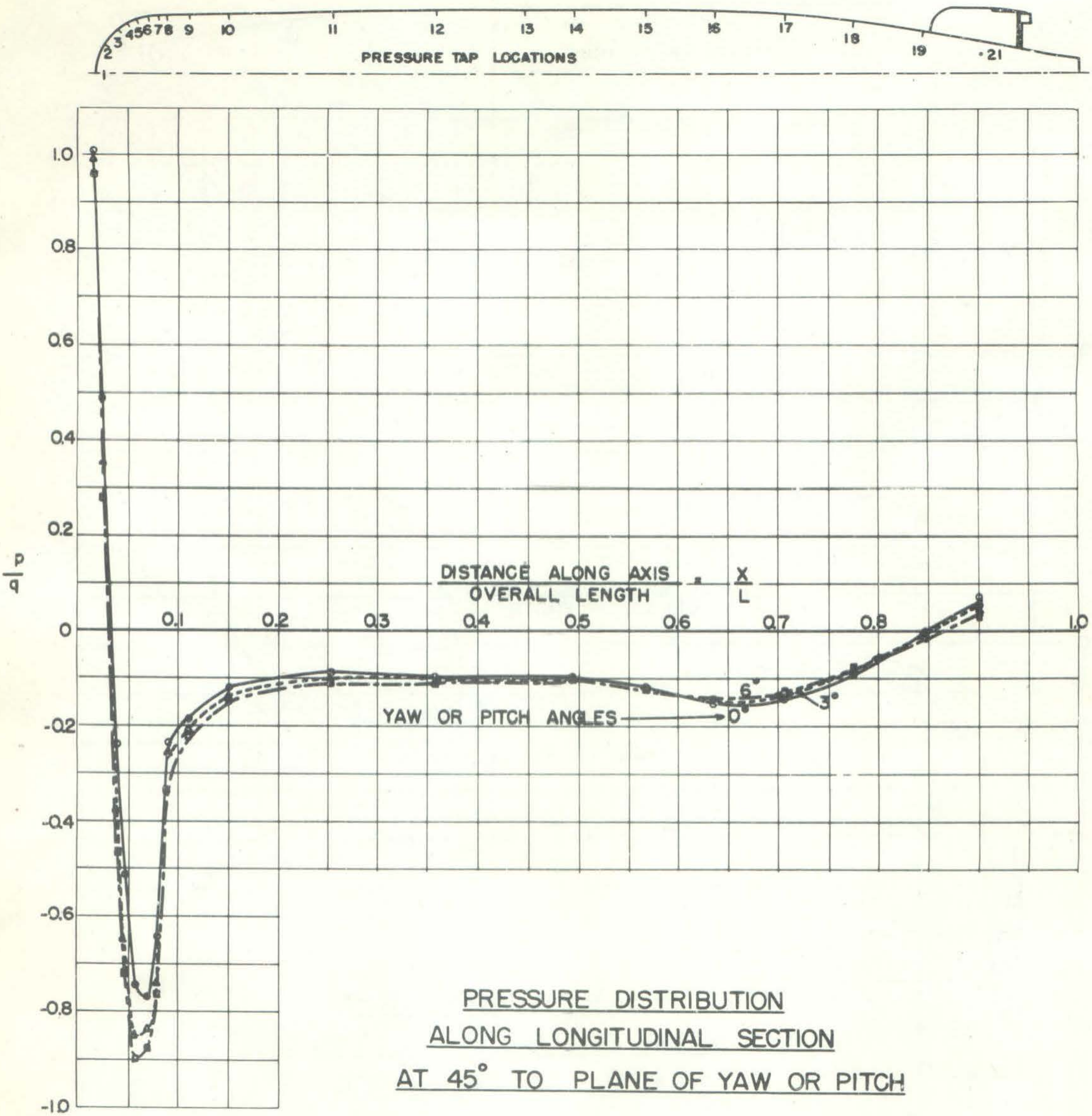
FIGURE 6



PRESSURE DISTRIBUTION
ALONG LONGITUDINAL SECTION
AT 45° TO PLANE OF YAW OR PITCH

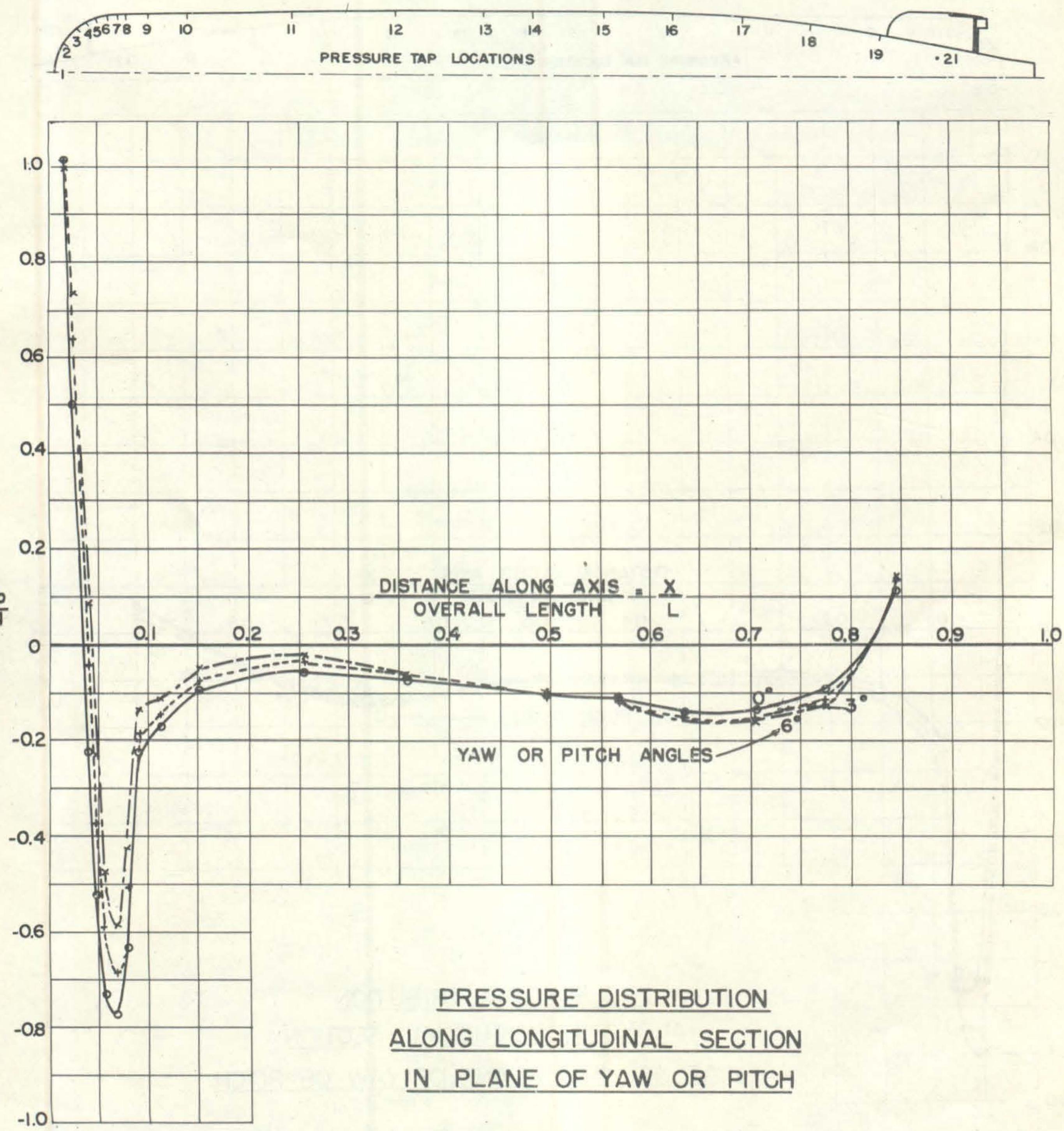
WINDWARD SIDE OF BODY WITH RING

FIGURE 7



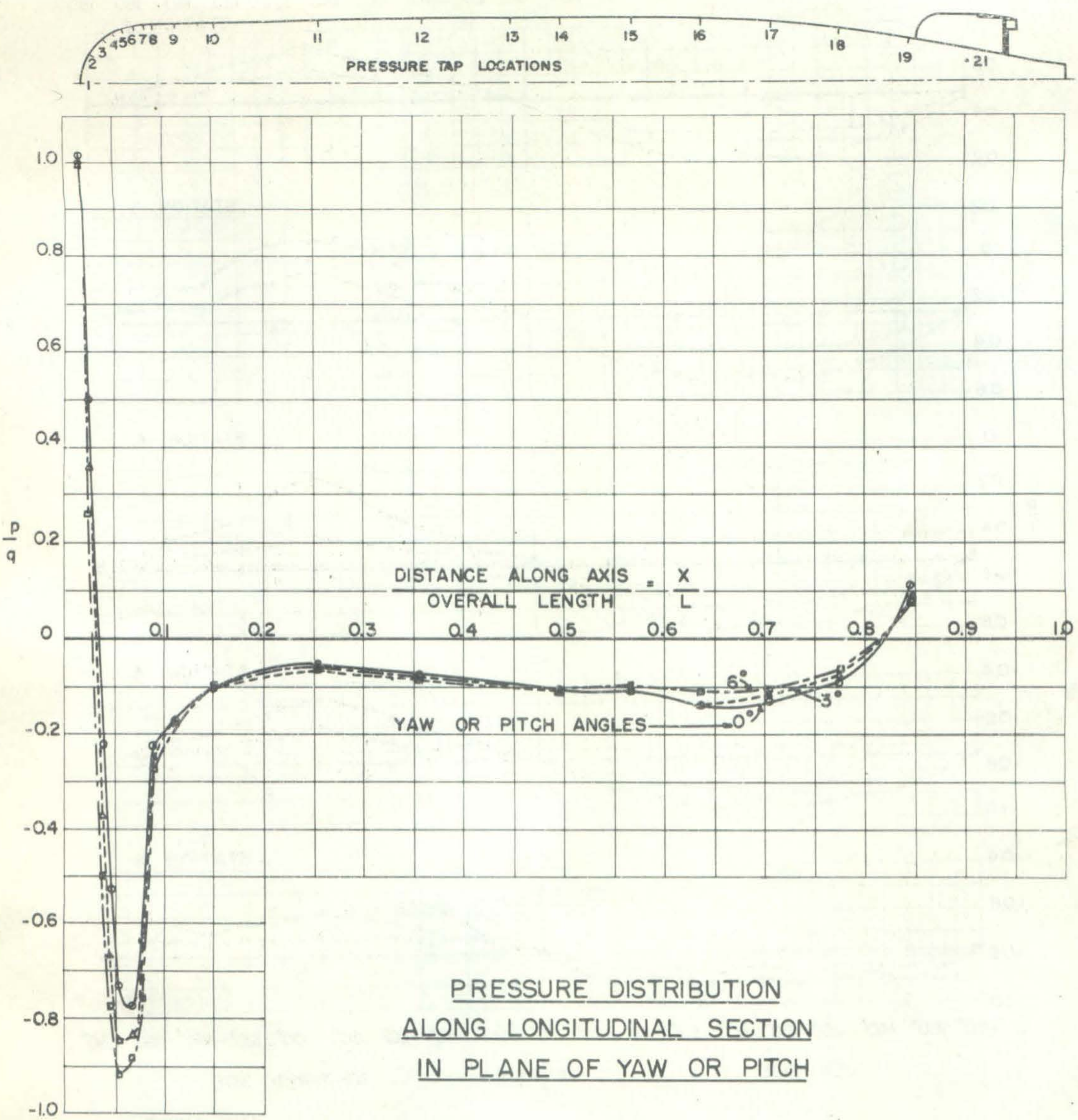
LEE SIDE OF BODY WITH RING TAIL

FIGURE 8



WINDWARD SIDE OF BODY WITH RING TAIL

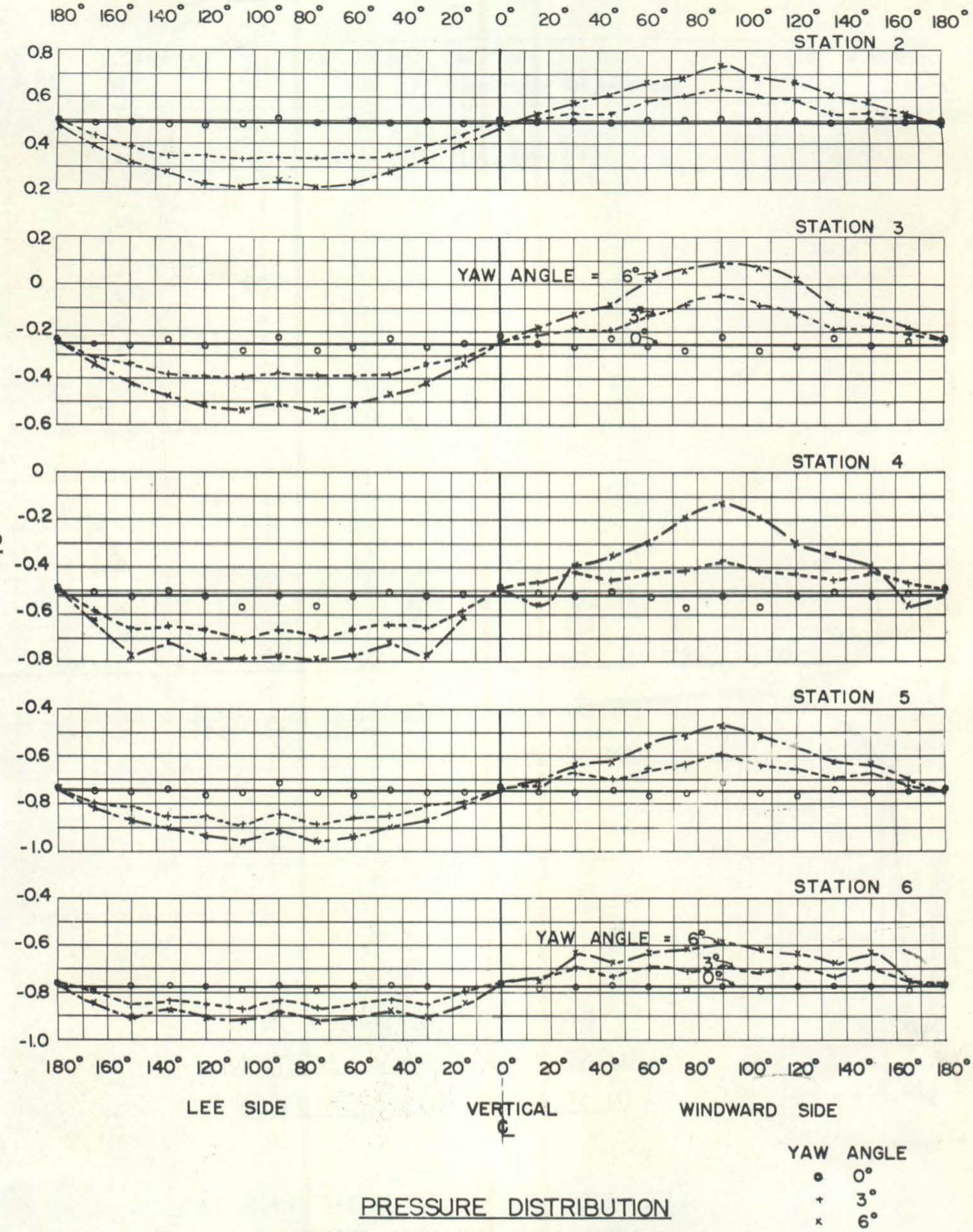
FIGURE 9



PRESSURE DISTRIBUTION
ALONG LONGITUDINAL SECTION
IN PLANE OF YAW OR PITCH

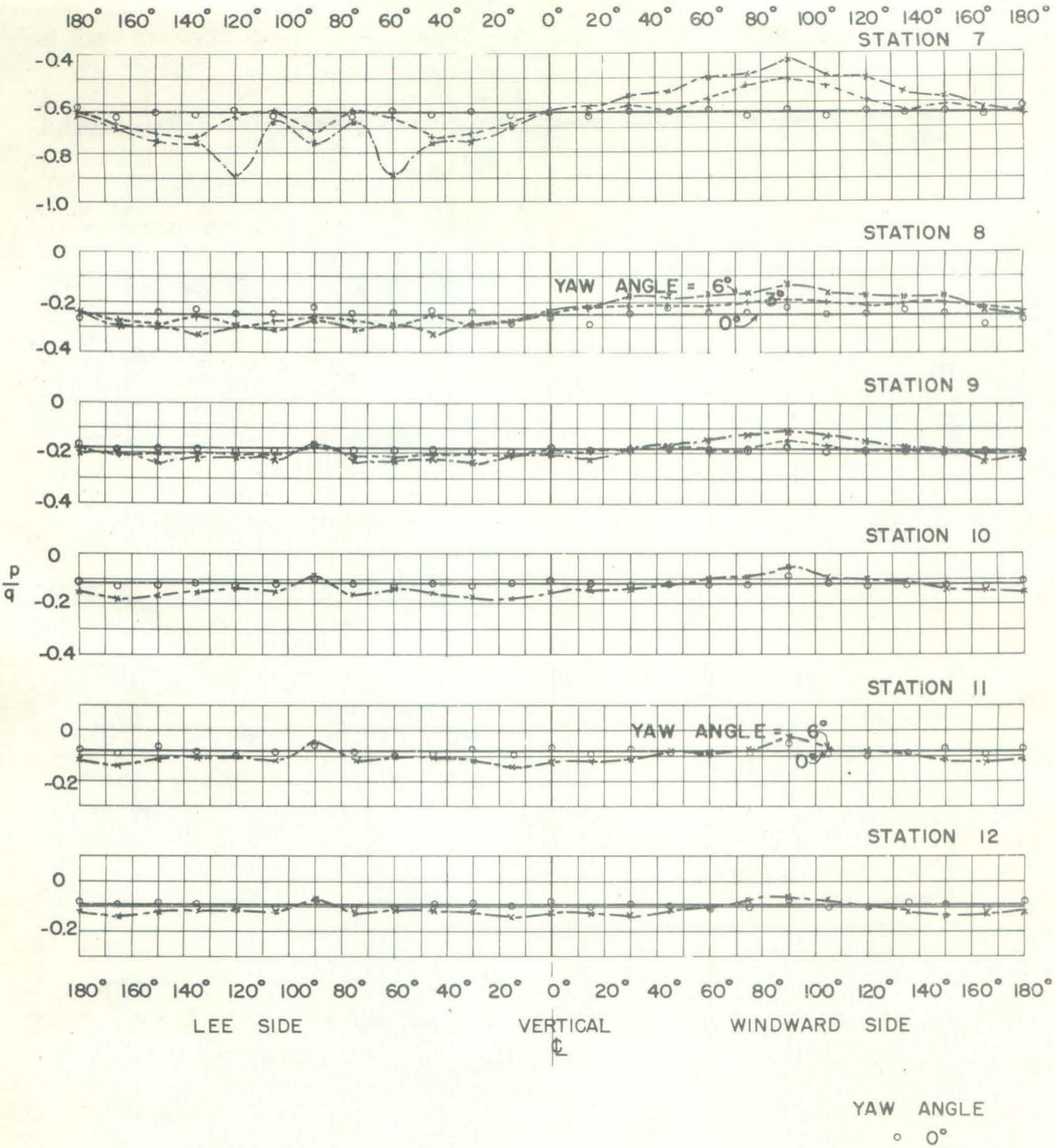
LEE SIDE OF BODY WITH RING TAIL

FIGURE 10



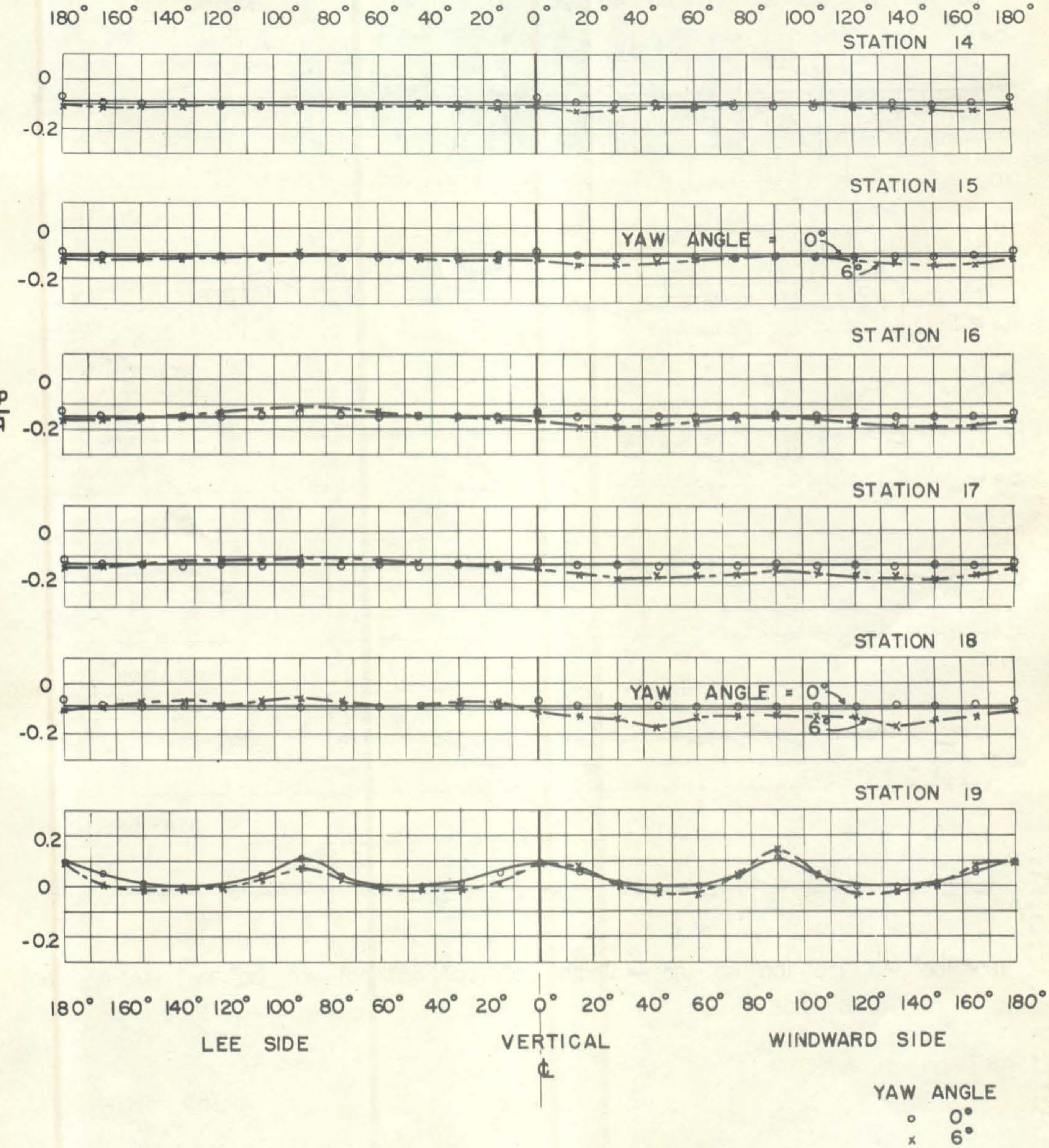
PRESSURE DISTRIBUTION
ABOUT NORMAL CROSSECTION
AT STATIONS ON FOREBODY

FIGURE 11



PRESSURE DISTRIBUTION
ABOUT NORMAL CROSSECTION
AT STATIONS ON FOREBODY

FIGURE 12



PRESSURE DISTRIBUTION
ABOUT NORMAL CROSSECTION
AT STATIONS ON AFTERBODY WITH RING TAIL

FIGURE 13

the pressure distribution when the torpedo is pitching, if we measure the body angles from the horizontal center line instead of the vertical. Also, the body angles may be reckoned from either end of the center line (i.e., either from top or bottom, or from port or starboard side) since the pressure distribution is symmetrical about the 90° points on windward and lee sides.

It will be noted that at Station 19, immediately ahead of the fins, the pressure on the body is equal to static pressure (p/q = o) at the 45° points between the fins, and rises to one-tenth of the dynamic pressure at the 90° points in front of the leading edges of the fins. Also, the effect of yaw on the pressure is practically negligible.

IV. CONCLUSIONS AND RECOMMENDATIONS

The tests reported herein show that the presence of the shroud ring on the tail does not affect the pressure distribution on the body of the torpedo. Therefore, the conclusions and recommendations given in Report 1643 for the ringless torpedo apply also to the torpedo with ring tail. The pertinent points are restated below.

1. The pressure on the surface of the torpedo equals the static pressure corresponding to the running depth or submergence at two positions, one on the nose and one on the afterbody (See Figure 5). Ahead and behind these two stations the pressure is above static, while between them (which includes about 82% of the body length) the pressure is below static.

2. The presence of fins on the afterbody causes local high pressure zones immediately in front of their leading edges, but produces no appreciable effect on the pressure midway between the fins. Consequently, the points where $P = P_o$ on the afterbody depend on the proximity of the fins.

3. The pressure on the afterbody where $P = P_o$ is only slightly affected by yaw or pitch angles up to 6° (see Figure 13).

4. The existing location of the pressure intake for depth control gives a pressure lower than the true hydrostatic pressure and causes the torpedo to run below set depth by several feet, the error depending on yaw or pitch angles and on velocity.

5. On the basis of these measurements (made without rotating propellers) true hydrostatic pressure, independent of speed and of small yaw or pitch angles, will be obtained if the pressure connections to the immersion gear are located on the 45° lines midway between the fins and about 23 inches ahead of the tip of the tail. The influence of the propellers may shift this point slightly.

6. The depth and roll recorder is so located in the exercise head of this torpedo that it is subject to a pressure which is lower than true hydrostatic pressure and, therefore, it records a depth shallower than the true running depth. With the depth control gear forcing the torpedo to lower than set depth as described in (4) above, the recorder may indicate approximately set depth for runs that are actually several feet too deep.

7. Placing the pressure take-off for the depth recorder where $P = P_o$ on the nose is not recommended because P changes rapidly in this zone and large errors may result from small errors in locating the connection. Taking the pressure from the afterbody is not feasible because of the physical obstructions inside the torpedo. It is recommended, therefore, that the data reported herein be used to estimate corrections to apply to depth records obtained with the recorder in its present location.